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MAGNETICALLY UNDETECTABLE ELECTRONIC CIRCUIT ASSEMBLIES

BY HAYDEN MORRIS

UNDERWATER SYSTEMS DEPARTMENT

3 OCTOBER 1980

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER NSWC/TR-80-441	2. GOVT ACCESSION NO. AD-A100669	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Magnetically Undetectable Electronic Circuit Assemblies		5. TYPE OF REPORT & PERIOD COVERED
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Hayden Morris		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Surface Weapons Center White Oak, Silver Spring, MD 20910		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 63502N; 0; S0260-MW/20360; OU19CAU31
11. CONTROLLING OFFICE NAME AND ADDRESS		12. REPORT DATE 3 October 1980
		13. NUMBER OF PAGES 28
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

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17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Microcircuits
Hybrid Microcircuits
Microelectronics
Hybrid Microelectronics
Magnetic Signature

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report describes the results ~~of work~~ concerned with fabricating electronic circuit assemblies which are undetectable magnetically, and contains recommendations concerning further development work.

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FOREWORD

The purpose of the work described in this report was to fabricate electronic circuit assemblies which are not detectable magnetically. Since electronic circuit assemblies having a magnetic signature of absolutely zero can be fabricated using hybrid microcircuit technology, the objective of the work became that of devising a hermetic package which also is undetectable magnetically.

The work was partially funded under a project concerned with mines sponsored by NAVSEA (PMS-4078).

The success of the work is acknowledged to be due to the contribution of efforts by the following individuals: H. W. Rhodes, through helpful discussions, and who, along with M. C. Marlow, fabricated the hybrid microcircuits based on the circuit designs of A. Delagrange and W. Wilson; E. W. Perry and O. E. Green, III, who processed the copper lead frame material; C. Adams who gold-plated the copper lead frames; M. H. Lackey, Jr., and W. E. Hetrick, who made magnetic measurements, and also D. Grenier who made magnetic signature measurements under test method WS 20522.

GEORGE P. KALAF
By direction

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INTRODUCTION

The Navy has a need for assembled electronic circuits which have the design feature of being non-magnetic, that is, which have the physical property of zero magnetic signature when measured by test method WS 20522. The magnetic signature of the components in an electronic circuit assembled in the conventional manner, is detrimental to the performance of certain ordnance devices and Swimmers' equipment. This characteristic magnetic signature is detrimental also to the performance of laboratory measuring systems, sensing devices, satellites, and medical implant electronics.

Techniques have been devised and are in use in the U14 Microelectronics Facility at Naval Surface Weapons Center, White Oak, for the fabrication of assembled electronic circuits which are undetectable magnetically.

PROCEDURES AND RESULTS

The magnetic signature of a standard electronic circuit is the result of the materials used in the fabrication and packaging of various components. Typical sources of magnetic signature are metals such as Dumet and Kovar which are used in the packaging of crystals and semiconductor devices; nickel, which is used to form the conductor patterns on ceramic and some printed circuit boards; various materials in capacitors; etc.

Electronic circuits having zero magnetic signature (ZMS) can be assembled. This is accomplished through the use of standard hybrid microcircuit technology. The term, hybrid microcircuit, denotes a special type of circuit fabrication technology which was developed to enable electronic circuitry to be fitted

into restricted spaces while achieving special performance characteristics and surviving severe environmental conditions. Today this technology is employed in a variety of applications such as military systems and space satellites, and in civilian commercial applications such as the touch-tone telephone, television sets, computer systems, automotive electronics, etc.

As an example, and to acquaint those individuals not working actively with hybrid microcircuit technology, a hybrid circuit is shown in Figure 1 and will be discussed in some detail. This circuit is assembled on a smooth ceramic substrate with dimensions 1.750 x .750 inches. The chromium/gold conductor pattern is delineated as shown in Figure 2, using photo-lithographic techniques resulting in minimum line widths and spacings of .005 inches. The integrated circuits, transistors, and diodes used in the design of this circuit were obtained directly from the manufacturer in the unpackaged chip form. The components are bonded in place using special epoxies. The interconnect wiring is accomplished using .001 inch diameter aluminum wire and ultrasonic wire bonding techniques. Resistors used in this circuit are also in chip form and measure .035 x .035 inches with resistor values ranging up to several hundred megohms. Resistor accuracy can be specified to one percent or less and the temperature coefficient of resistance can be provided with positive, negative or zero values measured in parts per million per degree centigrade. The capacitors are also in chip form and can have specified accuracies to at least one percent and temperature coefficients such as 30 parts per million per degree centigrade. Ceramic chip capacitors for hybrid microcircuits range in value from a few pico-farads to several micro-farads, with dimensions ranging from .050 x .080 x .050 inches thick to .245 x .225 x .080 inches thick. The working voltage can be 50 volts or greater. Components such as crystals, shown at the lower left in the circuit in Figure 1 are also available for hybrid microcircuit assemblies.

Since the magnetic signature of a hybrid microcircuit is zero, the problem then is to house the circuit in a hermetic package and maintain the magnetic signature at absolutely zero. Workers on other projects attempted to solve the problem by using moulded epoxies or conformal plastic coatings with external leads of beryllium copper. These methods failed when the assemblies were

subjected to environmental testing due to the interconnection bonds being broken by the conformal coating and potting materials.

In consideration of the microcircuit packaging problem, materials were evaluated as to the magnetic signature when measured in milligauss. The materials found to have a magnetic signature of zero are listed in Table I. Additional information regarding the magnetic permeability and susceptibility of materials was obtained from books by F. Rosebury[1], and also by R. C. Weast and S. M. Selby[2]. As a result of this background information and knowledge of ceramic microcircuit package technology, it was believed that a non-magnetic package could be developed using metallized alumina ceramic and other non-magnetic materials.

The microcircuit packaging method devised at Naval Surface Weapons Center, White Oak, is shown in Figure 3. This packaging technique relies on the use of a standard type alumina ceramic flat package[3], but which was modified as to the conductor metallization and the material used for the external leads. The cover used in this work was metallized ceramic, but Danalloy[4], a special non-magnetic alloy, could be used since it matches the thermal expansion coefficients of alumina ceramic. The medium for hermetically sealing the cover to the circuit substrate holder can be low temperature glass or solder, epoxy, or welding. The sealing method is dependent on the type of cover used and the reliability requirements.

The reason for modifying the conductor metallization used ordinarily on ceramic was to eliminate the layer of nickel. The purpose of the nickel is to promote wetting during the brazing operation for attachment of the external leads. The modification was accomplished by plating and sintering the 100 micro-inches of gold-plating directly on the refractory metallization[5]. The second modification to the standard ceramic package was the use of gold-plated copper instead of Kovar as the material for the external leads.

Of the many references in the literature on the use of copper as material for external leads on ceramic microcircuit packages, the earliest was found to be that by M. O. Samuelson and L. M. Schneider[6] for a NASA space project.

Parallel gap welding techniques were used to attach the leads. Later work involving the attachment of gold-plated copper leads using thermocompression bonding techniques, was reported by R. W. Ilgenfritz, L. E. Mogey, and D. W. Walter[7], followed by work at Bell Telephone facilities[8-13] in which the satisfactory reliability of copper leads was also reported. Still later, R. J. Blazek and W. A. Piper[14] reported on the specific parameters which should be controlled to achieve reliable thermocompression bonding of external copper leads. In all the work cited above using thermocompression bonding techniques, specialized equipment was used. Fortunately, as described by R. W. Berry, P. M. Hall, and M. T. Harris[15] and later by D. Baker, et al[16], parallel-gap welding techniques can be used to achieve both thermocompression (solid-phase) welds and fusion welds. Therefore, it was decided to use parallel-gap welding equipment for attachment of copper leads in this work.

The welding process parameters were determined and the process was carried out under an atmosphere of forming gas (10% H_2 and 90% N_2). The electrode spacing was from .003 to .005 inches with the applied voltage approximately 0.90 volts; the weld duration time of 18 milli-seconds; and the applied force of not less than 125 grams. The welding tip material was tungsten with cross-sectional areas of .008 x .015 inches. It was found that the welds made in this manner with .002 inch thick gold-plated copper resulted in bonds such that when the lead was pulled, the copper was torn before any damage was caused to the weld joint itself.

A novel type of package assembly is shown in Figure 4. The ceramic cover shown for this assembly has metallized areas extending from the sealing surface. The purpose of this configuration is to enable the cover to be sealed to the substrate holder with less heat input. This is accomplished by passing the heating current directly through the metallization on the sealing surface of the ceramic cover and the solder preform[17]. The extended areas of the cover are not gold plated and so the solder remains in the area of the sealing surfaces which are gold plated.

CONCLUSIONS

Assembled electronic circuits having zero magnetic signature can be fabricated and enclosed in a hermetically sealed package which also has a magnetic signature of zero.

As a result of the various inquiries concerning magnetically undetectable electronic assemblies, it is concluded that there are many Navy projects which require technology of this type.

RECOMMENDATIONS

The following recommendations are made based on experience with this work and also the inquiries concerning other Navy projects.

1. The ceramic package should be of such a design that substrates .025" thick can be used, and package depth great enough to accommodate hybrid circuit components and the tooling used in making the interconnect wire bonds. A package design which satisfies these requirements is shown in Figures 5, 6, and 7. The design also has the capability of being used with solder attached lead frames due to the longer metallization area for external lead bonding.

2. Because of inquiries from various Navy projects, which require smaller hybrid microcircuits, metallized ceramic packages should be made available which have the design features shown in Figures 8 through 11. The packages are designed to accommodate substrates 1.000 x .750 x .025 inches thick and .750 x .750 x .025 inches thick.

3. As a result of this work, it is recommended that thicker copper material, .005 to .007 inches, be used on packages of this type.

4. It is also recommended that to save time when producing packages in quantity, the lead attachment be made by gang bonding using thermocompression techniques or soldering techniques. The solder attached lead frames could be of a design as shown in Figure 12, with the material being copper or brass. The reliability and technology of solder attached leads have been described in the literature [18].

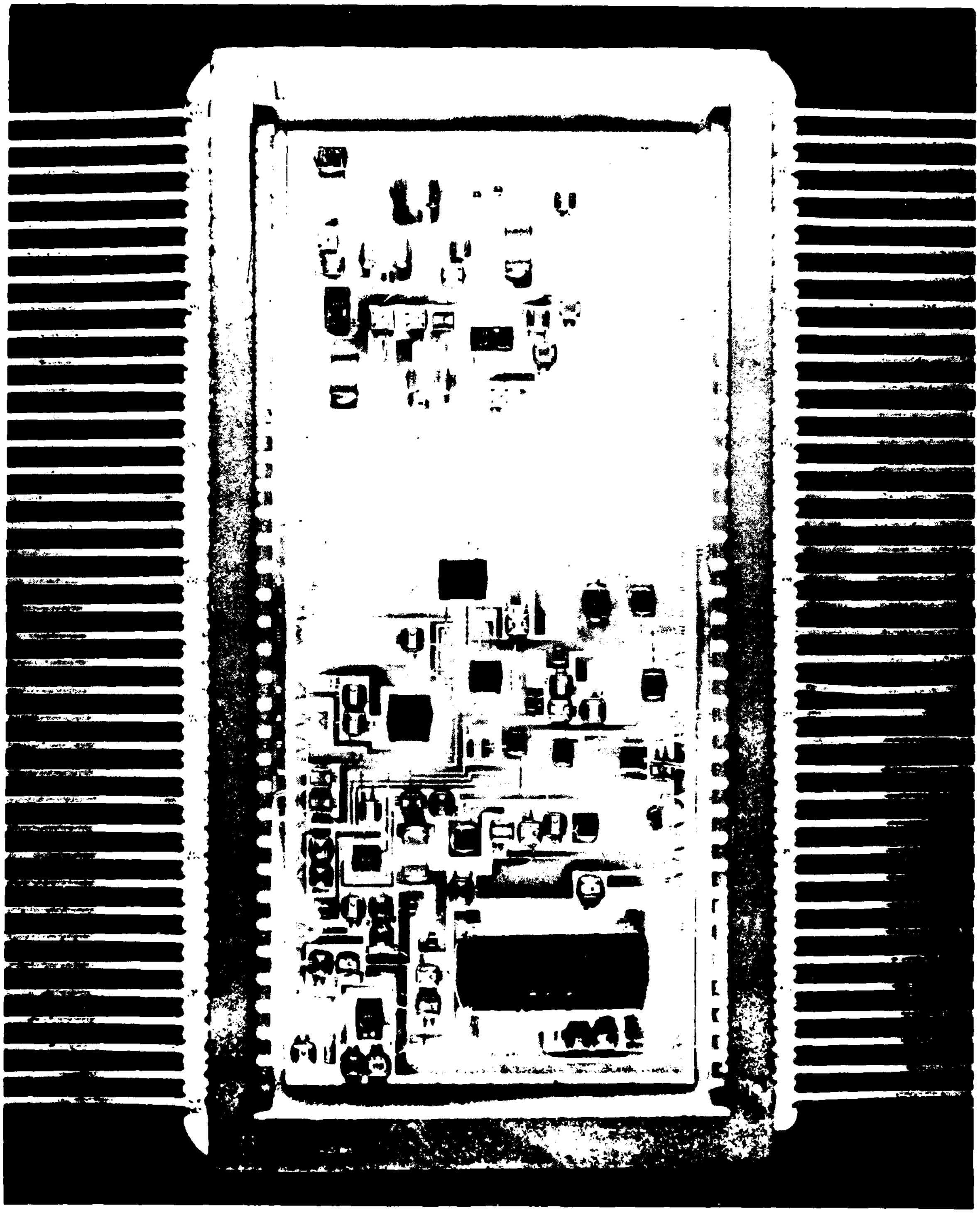


FIGURE 1 HYBRID MICROCIRCUIT

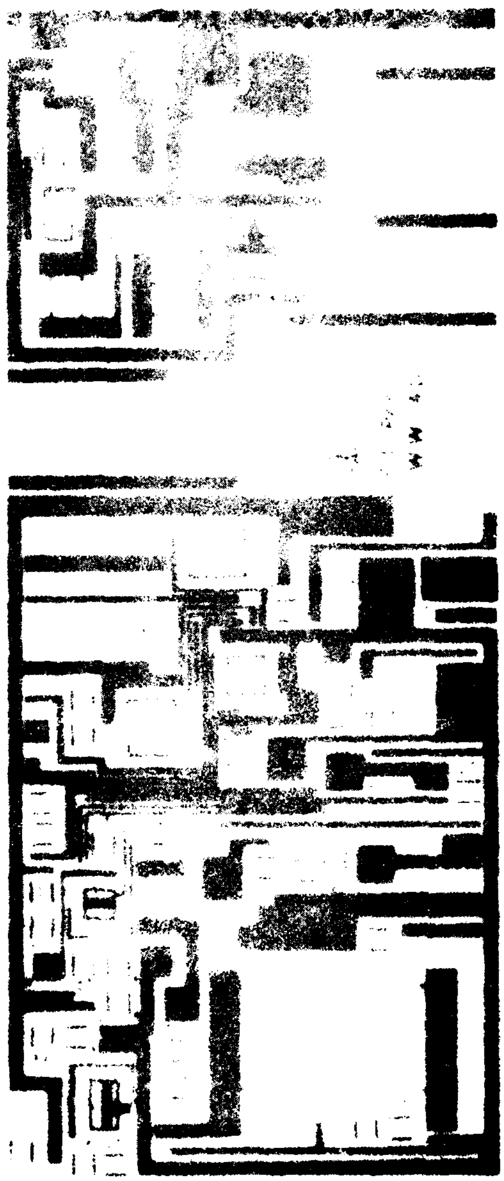


FIGURE 2 MICROCIRCUIT SUBSTRATE

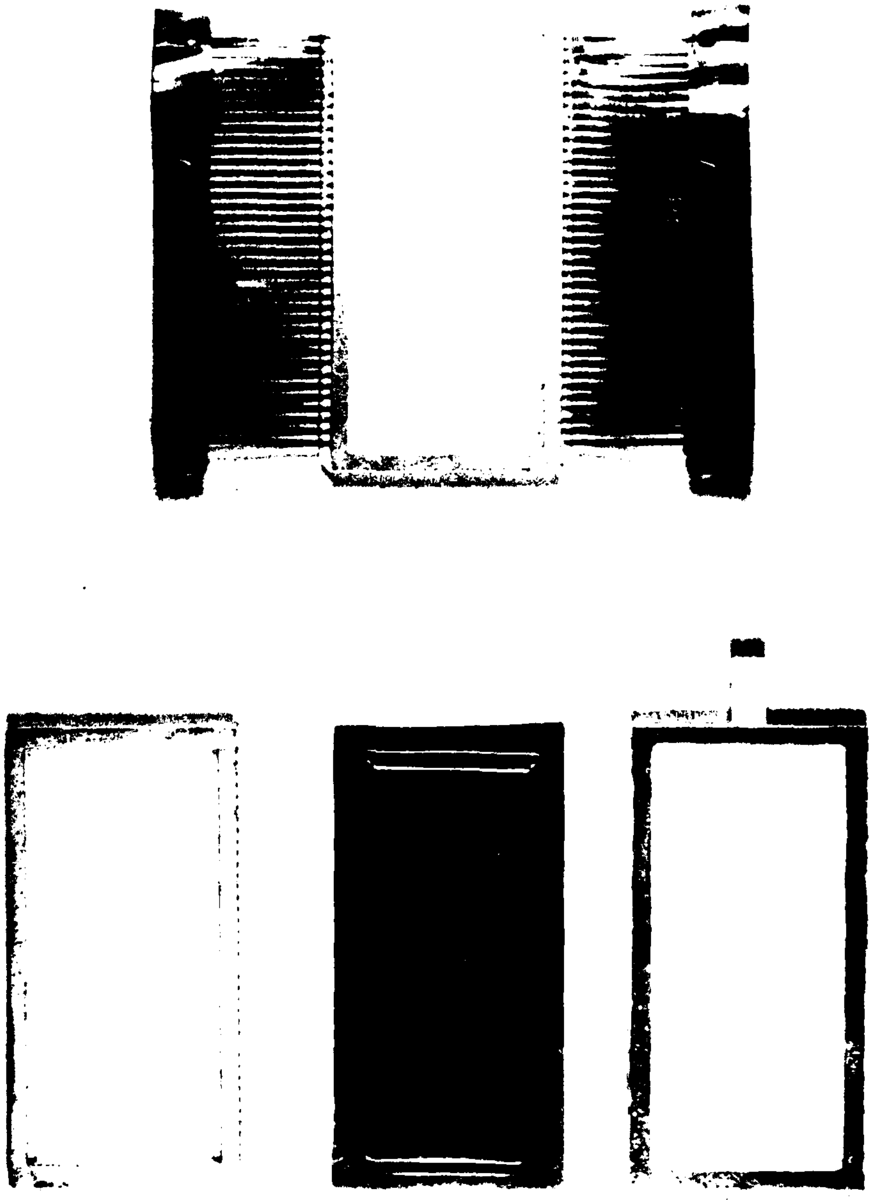


FIGURE 3 NON-MAGNETIC PACKAGE

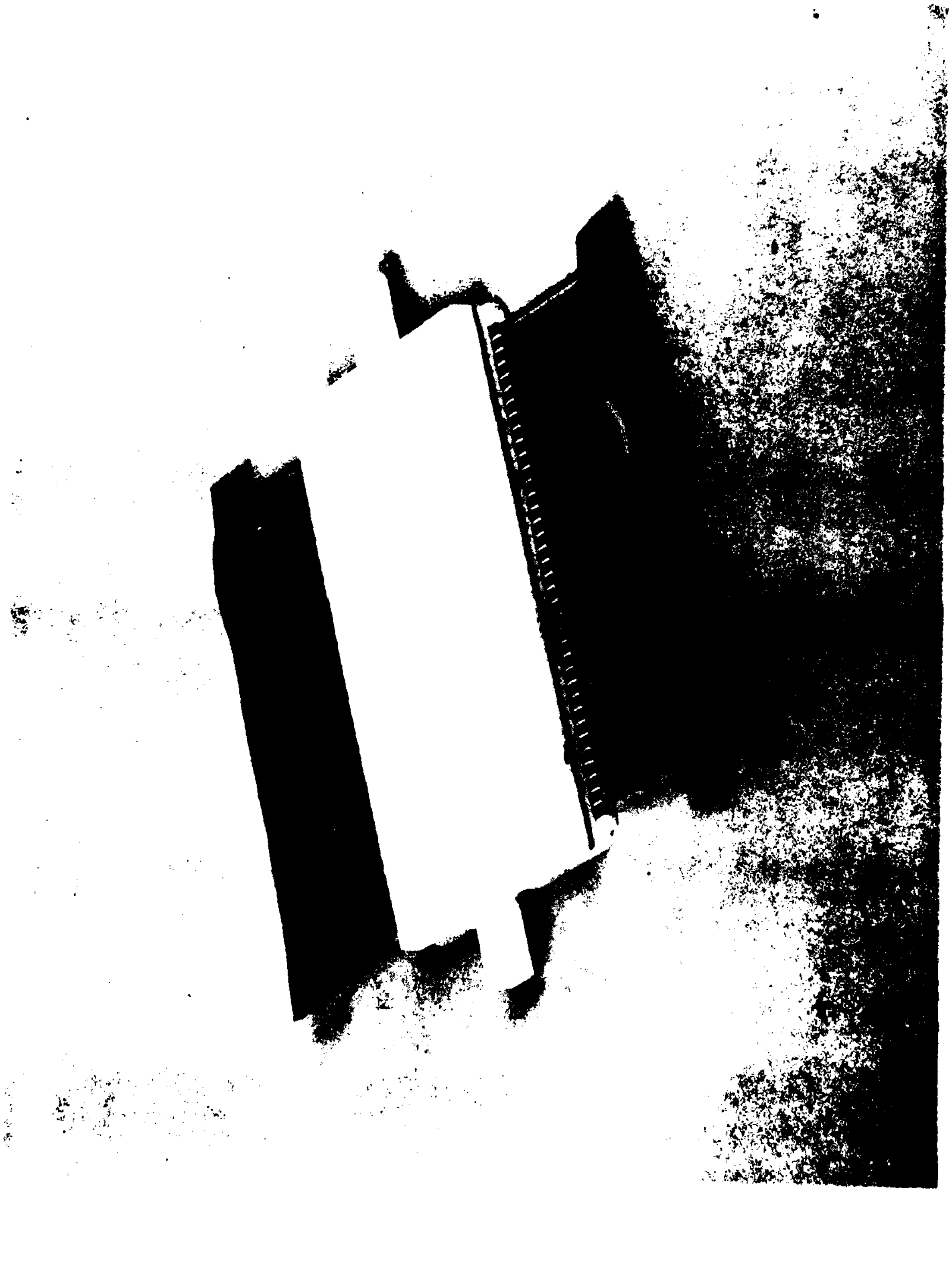


FIGURE 4 CERAMIC PACKAGE ASSEMBLY

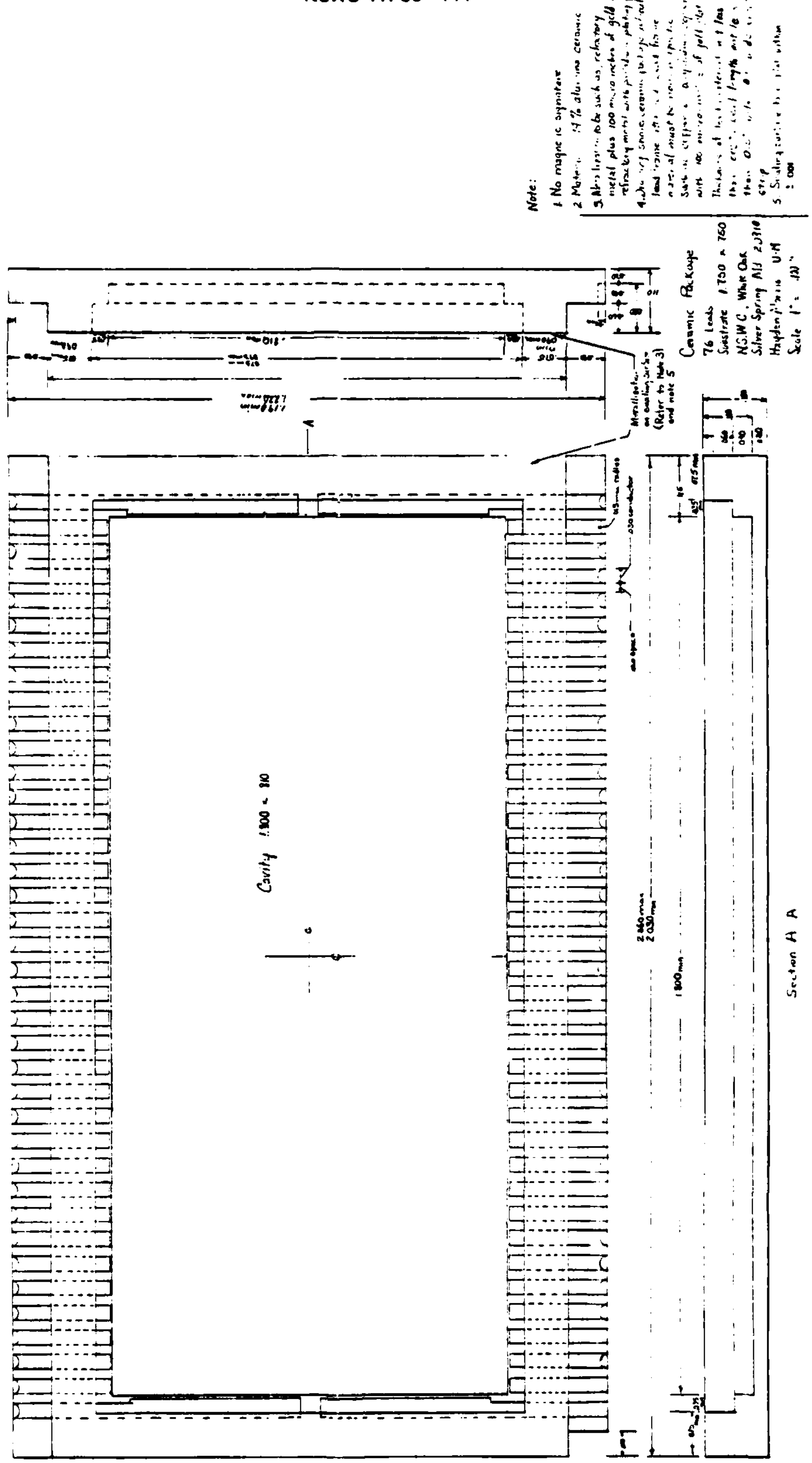


FIGURE 5 PACKAGE SUBSTRATE HOLDER FOR SUBSTRATE 1.75 x 0.750 x 0.025

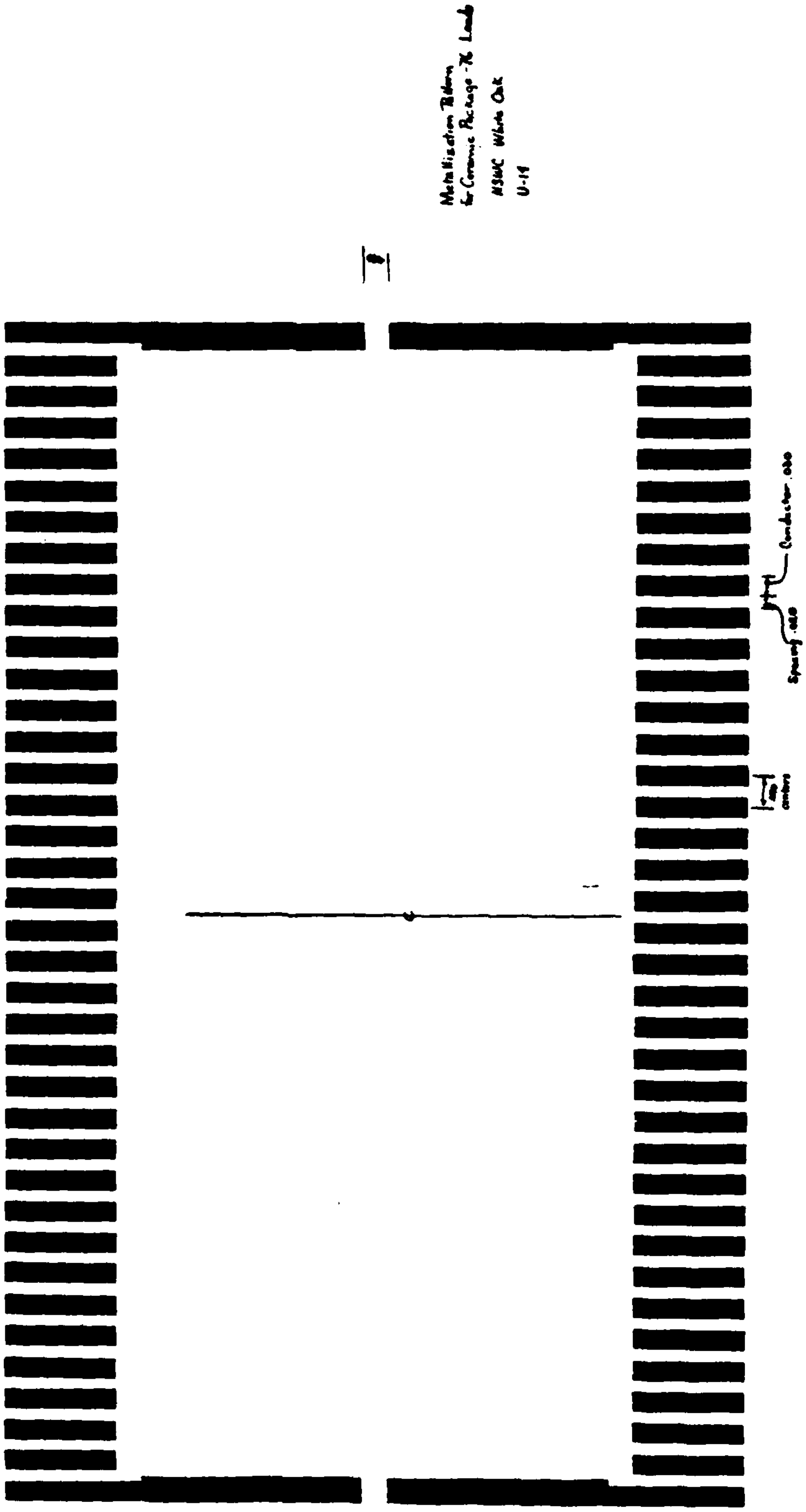


FIGURE 6 CONDUCTOR PATTERN FOR PACKAGE

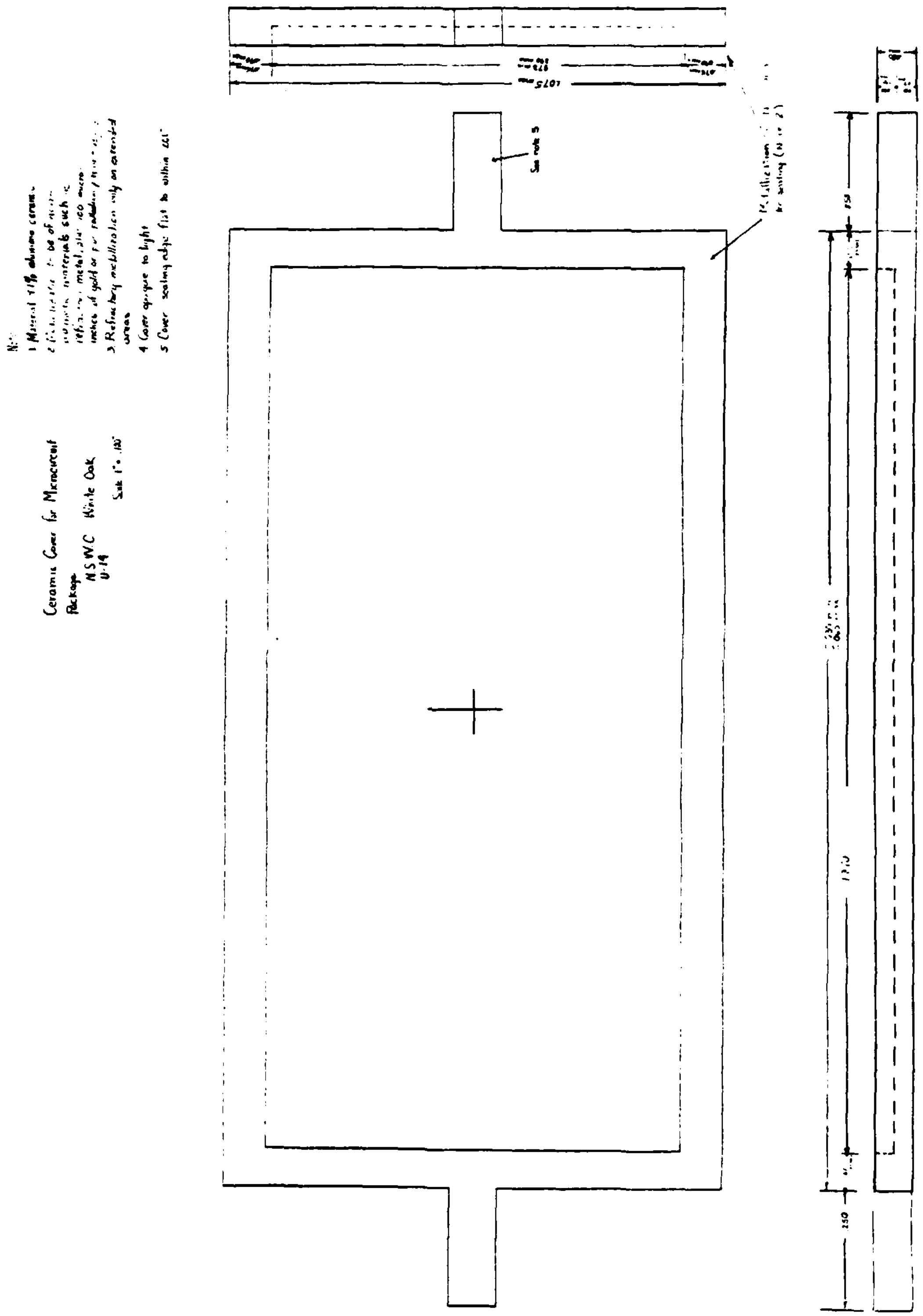


FIGURE 7 CERAMIC PACKAGE COVER DESIGN

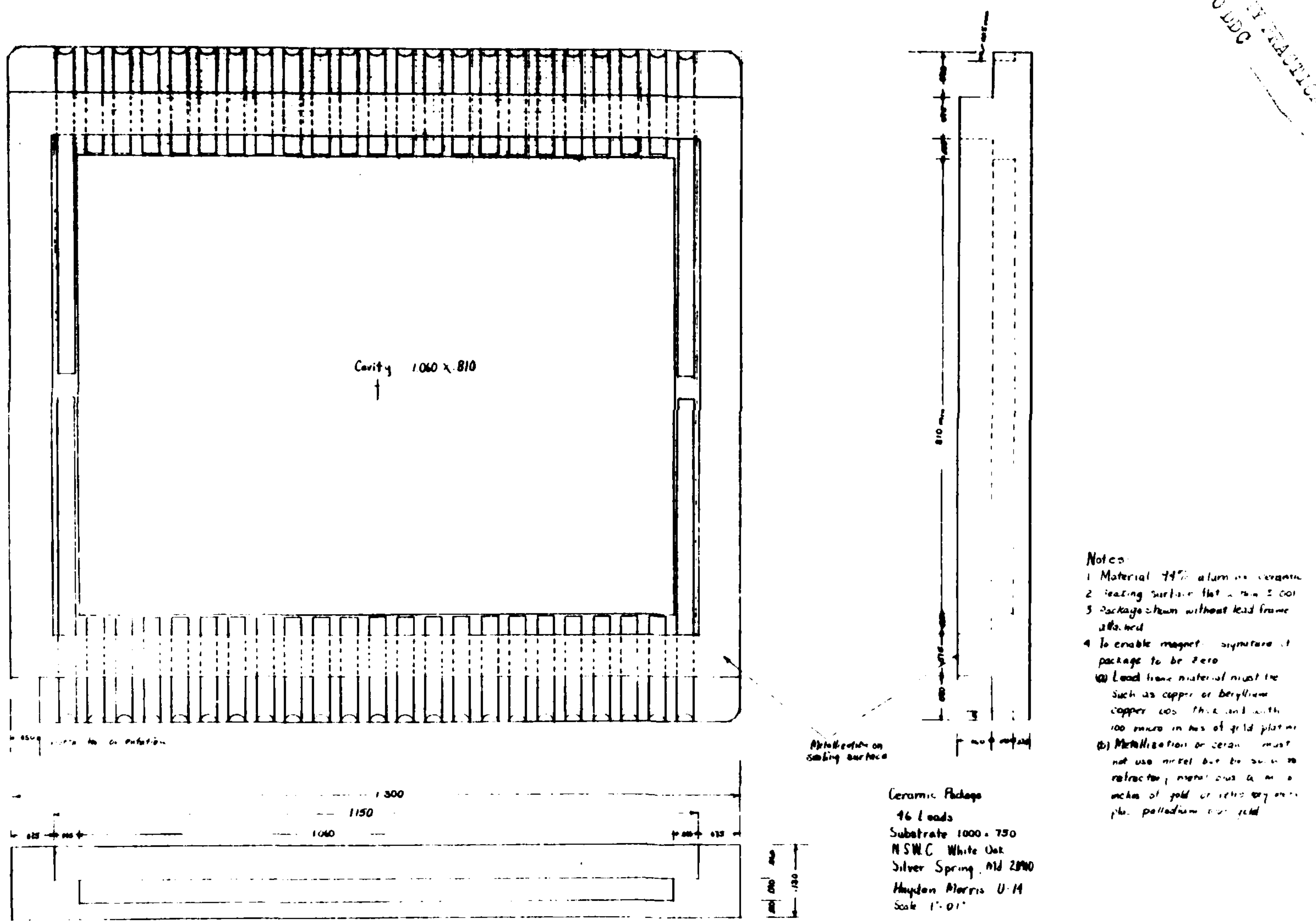


FIGURE 8 PACKAGE DESIGN FOR 1.000 x 0.750 x 0.025 SUBSTRATE

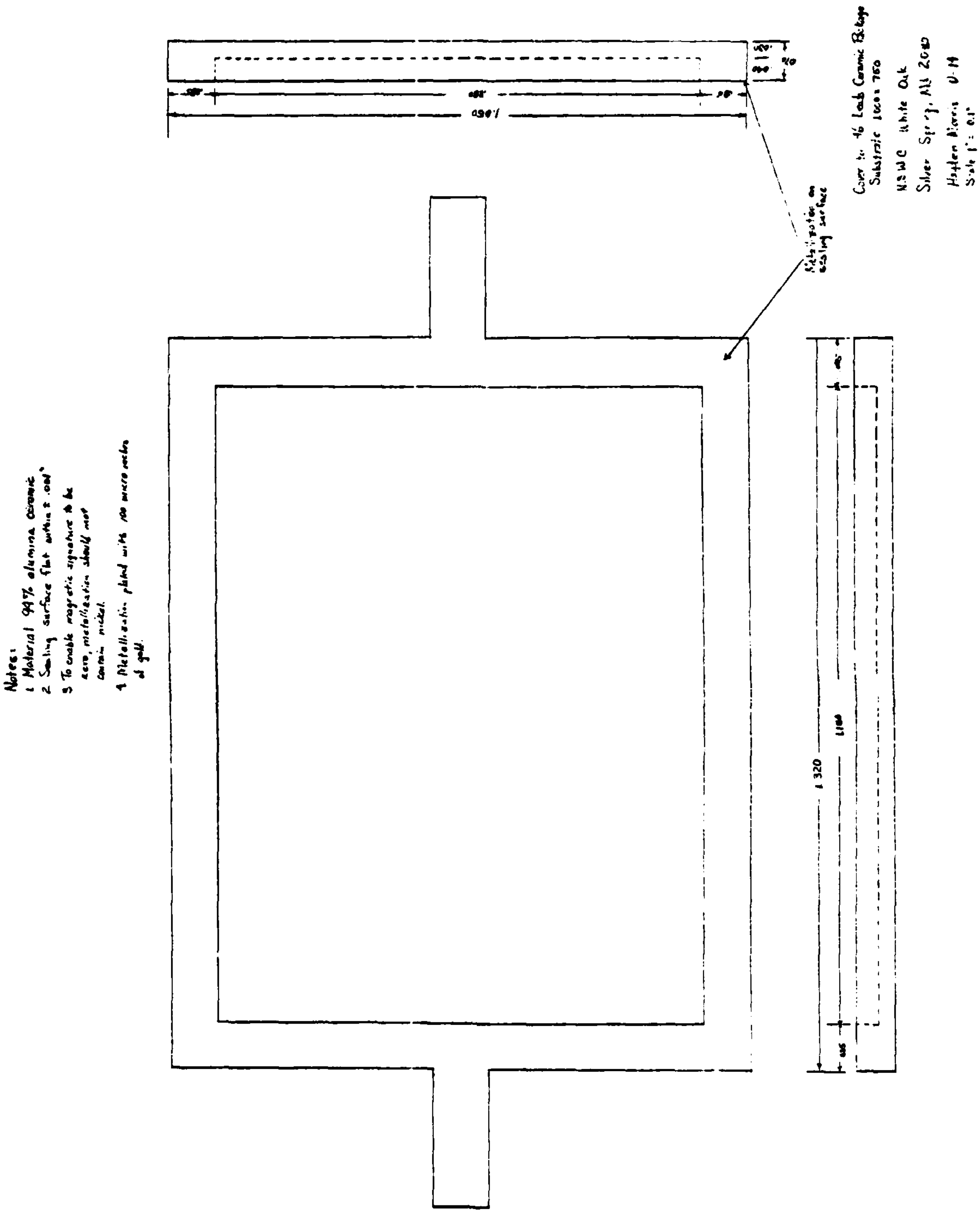


FIGURE 9 CERAMIC PACKAGE COVER DESIGN

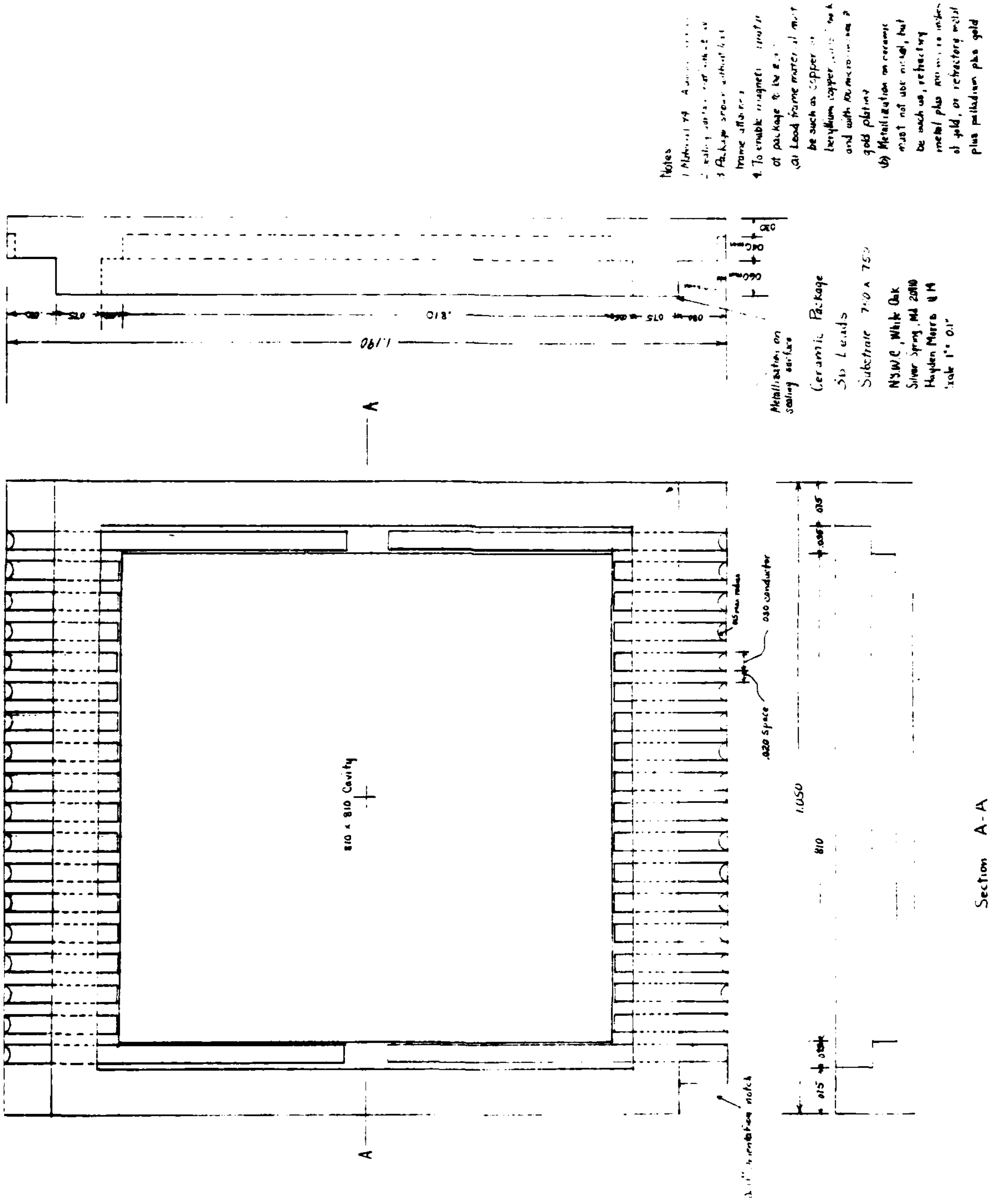


FIGURE 10 PACKAGE DESIGN FOR 0.750 x 0.750 x 0.025 SUBSTRATE

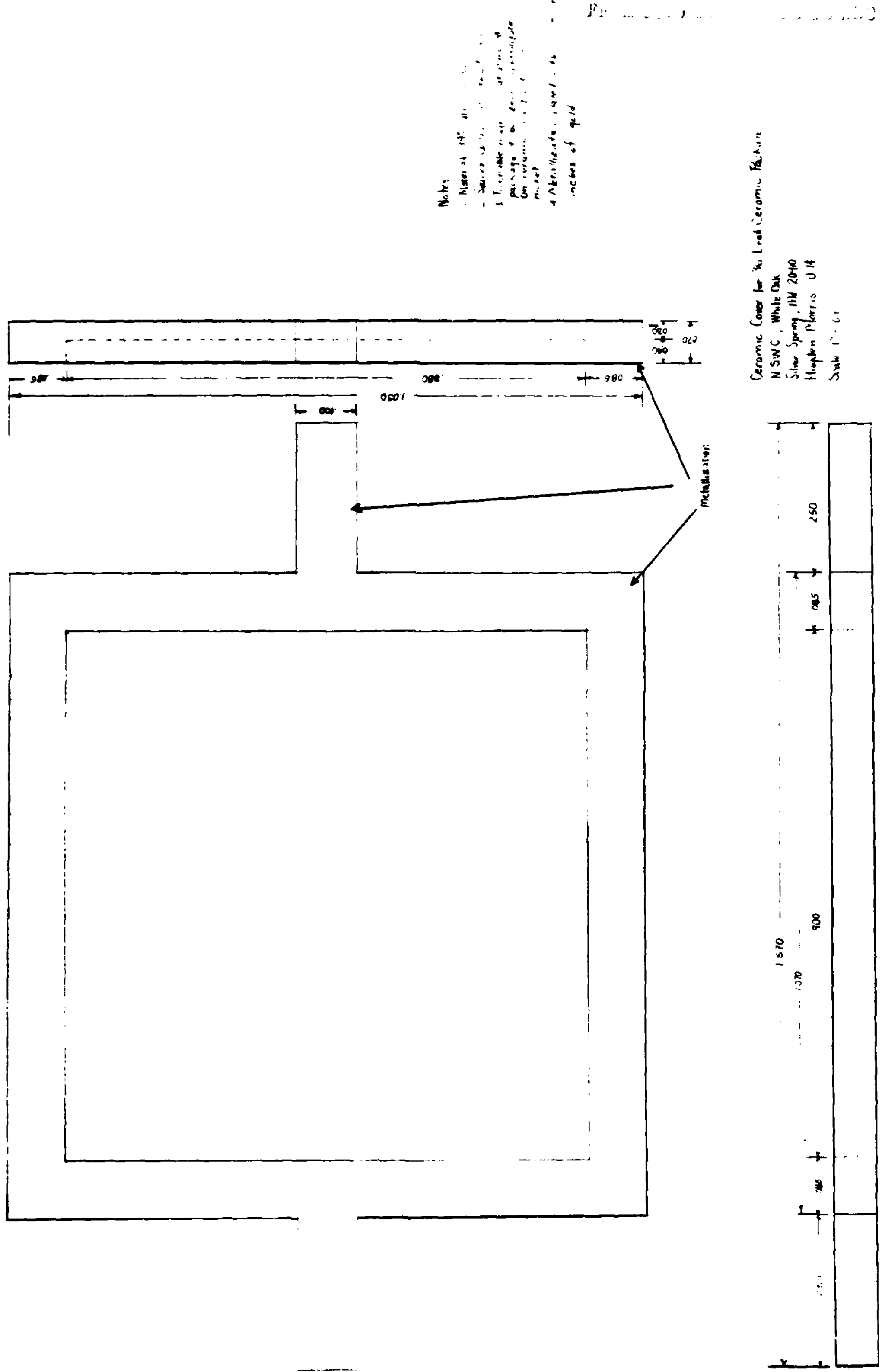
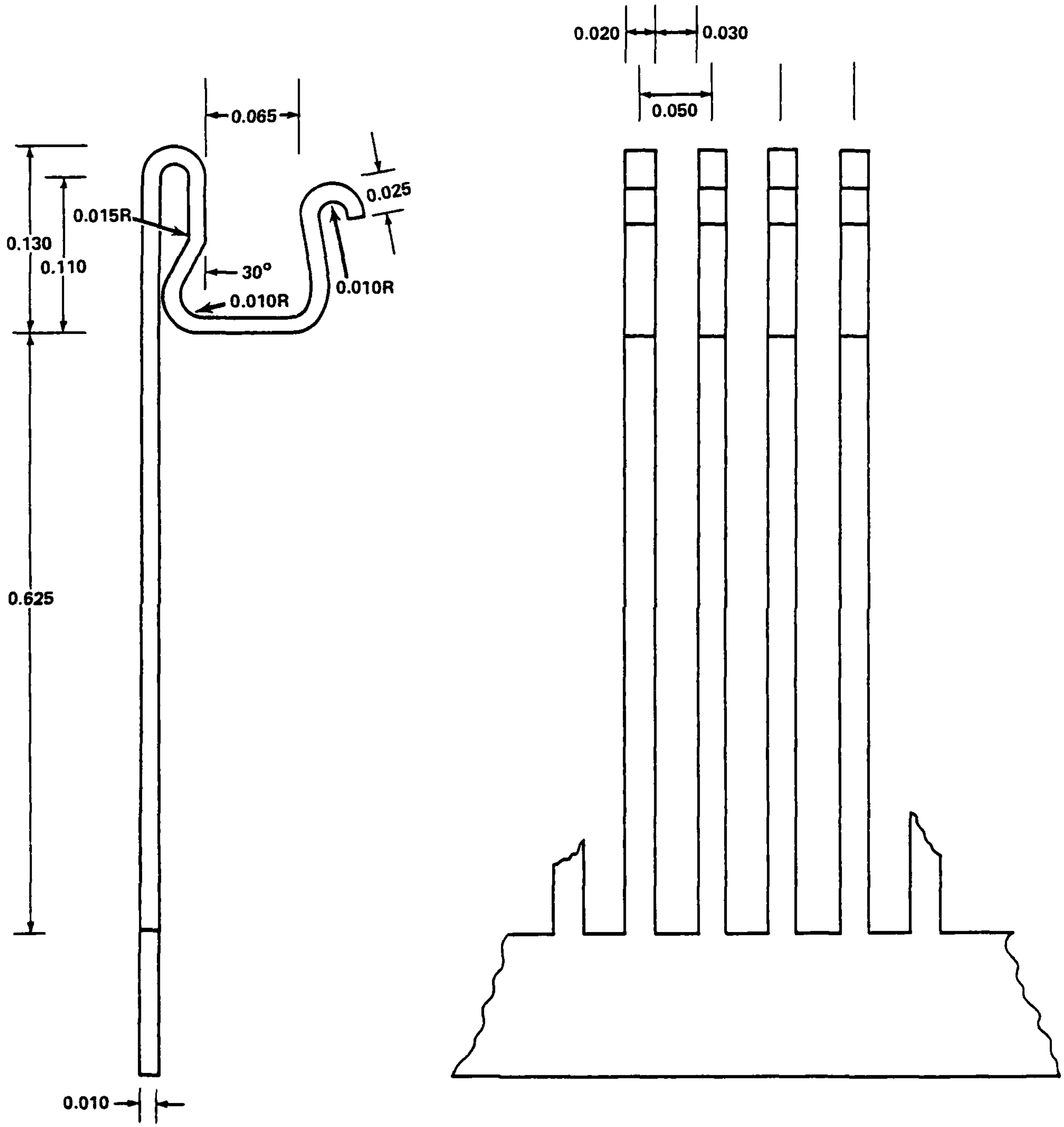


FIGURE 11 CERAMIC PACKAGE COVER DESIGN



MATERIAL: BERYLLIUM COPPER OR BRASS

SOLDER ATTACH LEAD FRAME

FIGURE 12 SOLDER ATTACH LEAD-FRAME DESIGN

TABLE I MATERIALS WITH ABSOLUTELY ZERO MAGNETIC SIGNATURE

Alumina Ceramic
Aluminum
Beryllium Copper
Chromium
Copper
Danalloy
Gold
Low Temperature Solder
Palladium
Silicon-Chromium
Titanium
Tungsten

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3. Type KD-78088, Kyocera International, Inc., 10050 N. Wolfe Road, Cupertino, California 96014.
Type SZ-82 6 37-A B, 3-M Company Electronic Products, St. Paul, Minnesota 55101

4. Danalloy is composed of silver alloyed with nickel, magnesium and gold. A product of Inland Electronic Products, 35 East Glenarm, Pasadena, California 91105.

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